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The Relation between Star Colours and Spectra. By W. S. Franks.

During an enforced leisure, I have made some investigations into the connection between the colours of stars and their spectra (see *The System of the Stars*, by Miss Clerke, p. 149), which may possibly be of interest to the Fellows of this Society. The material was gathered from the following sources. For *colours* of the brighter stars, I used the mean values of the observations made by members of the B.A.A. in 1890–3, and published in vol. i. part 3 and vol. ii. part 4 of the *Memoirs* of that Association,—the 928 stars selected depending on about 30,000 observations; they extend from the N. Pole to 25° south declination. For *southern* stars, between − 25° and the S. Pole, I made use of the observations by the New South Wales star colour section, published in B.A.A. *Journal*, vol. vi. p. 416 and vol. viii. p. 17. The number of southern stars selected was 432, resting on nearly 5000 observations; the aggregate is therefore 1360 of the brighter stars in both hemispheres. The same colour symbols were used throughout—they are published in the *Monthly Notices*, vol. xlvii. p. 269. The spectra were derived from vol. xxviii. part 2 of the *Harvard Annals* for the southern objects; and for the remainder, from *H.A.*, vol. xlviii. part 4 (catalogue of 1520 bright stars).

At the commencement I made a careful analysis of the colours and spectra of the southern stars, entering all in tabulated form under the 24 headings into which the spectra were divided—a condensed summary of which is seen in Table I. The same was done for the northern stars, as shown in Table II. Table III. is a list of the most obvious *discordances*, which amount to about 2½ per cent. of the whole. Table IV. gives the results of Tables I. and II. combined, and is probably the most trustworthy for generalisation.

Table I.

Summary of Analysis of 432 *Southern Stars from* − 25° *to S. Pole.*

Group.	Division.	Spectra.	Type.	O	YG^1	Y^1	OrY^1	Y^2	OrY^2	Or^2	Y^3	OrY^3	Or^3	OrR^3	R^3	Stars
1	I*a*.	Oa to B9A	Helium stars	46	50	43	6	6	2	...	...	...	...	...	...	153
2	I*b*.	A to A5F	Hydrogen stars	7	9	28	9	13	...	...	...	...	...	...	...	66
3	I.–II.	F to F5G	α Carinæ type	1	5	6	6	11	8	...	5	...	...	...	...	42
4	II.	F8G to G5K	Solar stars	...	3	2	5	7	11	...	5	3	2	...	...	38
5	II.–III*a*.	K	Arcturus type	...	...	1	5	4	31	6	6	8	6	...	...	67
6	II.–III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	2	7	1	1	10	20	6	...	47
7	III.	Ma to Md	Betelgeuse type	...	...	...	1	1	3	...	...	2	9	1	2	19
			Total	54	67	80	32	44	62	7	17	23	37	7	2	432

Notes.—Three G^1 included with O; two YG^2 with YG^1; two OrR^2 with Or^2; two OrY^4 with OrY^3; six Or^4 with Or^3; two OrR^4 with OrR^3; and one spectrum Q (Peculiar), η Carinæ, in R^3.

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TABLE II.

Summary of Analysis of 928 *Northern Stars, etc., from* – 25° *to N. Pole.*

Group.	Division.	Spectra.	Type.	O	YG^1	Y^1	OrY^1	Y^2	OrY^2	Or^2	Y^3	OrY^3	Or^3	OrR^3	Stars.
1	I*a*.	Oe to B9A	Helium stars	79	19	26	2	2	1	...	...	...	...	...	129
2	I*b*.	A to A5F	Hydrogen stars	161	71	76	2	1	...	...	...	...	...	...	311
3	I.-II.	F to F5G	α Carinæ type	2	6	72	2	12	...	...	1	...	...	...	95
4	II.	F8G to G5K	Solar stars	...	...	24	7	70	18	4	16	2	1	...	142
5	II.-III*a*.	K	Arcturus type	...	...	2	7	82	37	3	41	2	...	...	174
6	II.-III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	2	11	3	6	6	...	...	28
7	III.	Ma to Md	Betelgeuse type	...	...	1	1	1	23	13	4	2	2	2	49
			Total	242	96	201	21	170	90	23	68	12	3	2	928

Notes.—One B^1 and one G^1 included with O; one Or^1 with OrY^1; and one Y^4 with Y^3. The spectrum type H in the "Draper" Catalogue (*H.A.*, vol. xxvii.) has been included under G5K, as it does not find a place in the later classification of the southern catalogue (*H.A.*, xxviii. 2).

TABLE III.

List of the Largest Discordances.

a. From Northern List (II.).

Star.	R.A. 1900 h m	Decl. ° ′	Spect.	Col.	Remarks.
κ Cassiop.	0 27·3	+62 23	B	OrY^1	Possibly *var.* in col.; previous obs. give O and Y^1.
P. III. 54 Cam.	3 21·0	+59 36	B9A	OrY^2	Certainly *yel.*; confirmed by previous obs.
P. III. 51 ,,	3 21·9	+58 32	B9A	OrY^1	Possibly *var.* in col.; previous obs. range from Y^1 to Y^3.
μ Persei	4 7·6	+48 9	G	Y^3	Strong *yel.*; confirmed by previous obs.
29 Can. Maj.	7 14·5	–24 23	Oe	Y^2	Col. confirmed by previous obs.
ξ Argûs	7 45·1	–24 37	G	Y^3	Strong *yel.*; confirmed by previous obs.
ρ ,,	8 3·3	–24 1	F5G	Y^3	My previous obs. make this YG^2?
ρ Ophiuchi	16 19·6	–23 14	B	Y^2	Col. confirmed by previous obs.
μ Aquilæ	19 29·2	+ 7 10	A?	Y^2	Decidedly *yel.*; previous obs. range between Y^2 and Y^3.
β Capri.	20 15·4	–15 6	G comp.	Y^3	The brighter component of the well-known double; decidedly *yel.*; the companion (A or A2F) appears *blue* by contrast, but in reality it is probably *white*.

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TABLE III.—*continued.*

b. From Southern List (I.).

Star.	R.A. 1900. h m	Decl. ° ′	Spect.	Col.	Remarks
s Eridani	2 36·0	−43 20	A	Y^2	Lines broad and ill-defined (*H.A.*, xxviii. 2).
α Carinæ	6 21·8	52 39	F	O	Col. confirmed by A. S. Williams.
κ Can. Maj.	,, 46·1	32 24	B2A	Y^2	Lines broad and ill-defined (*H.A.* xxviii. 2).
χ Carinæ	7 54·2	52 43	B3A Pec.	OrY^2	Either spectrum or colour wrong?
Lac. 3105 Puppis	,, 55·3	48 58	B1A	Y^1	Spect. binary; fainter component B3A (*H.A.*, xxviii. 2).
d Velorum	8 40·8	42 17	G5K	YG^1	Col. too pale for type of spectrum.
A Centauri	11 30·0	53 42	B8A	OrY^2	Spectrum or colour wrong?
β Hydræ	,, 47·9	33 21	B9A	Y^2	Do.?
γ Crucis	12 25·6	56 33	Mb	Y^2	But A. S. Williams makes it OrR^3, which agrees with spectrum.
g Centauri	13 43·6	33 58	Mb	OrY^1	Spect. clearly type III.; col. wrong?
v^1 ,,	,, 52·5	44 19	B3A	Y^2	Spectrum or colour wrong?
θ ,,	14 0·8	35 52	K	Y^1	This type is strongly *yel.*; *maximum* falls in OrY^2.
V ,,	,, 13·3	55 56	B5A	YG^2	Possibly this ought to be YG^1?
μ Lupi	15 11·5	47 31	B8A	Y^2	Spectrum or colour wrong?
γ Circini	,, 15·4	58 58	B5A	Y^2	A. S. Williams makes this O. It is a composite spectrum; the other component F8G or G nearly = mags. (*H.A.*, xxviii. 2). Possibly spect. binary, with colour changes?
k Lupi	,, 18·8	38 22	A	Y^2	Spectrum or colour wrong?
η Normæ	,, 55·8	48 57	G5K	YG^1	Do.?
ε ,,	16 19·8	47 20	B5A	Y^2	Composite spect., other component type I. (*H.A.*, xxviii. 2).
τ Scorpii	,, 29·7	28 0	B	Y^1	Tupman, Gage, and Baracchi make it O, which is probably correct.
θ Aræ	17 58·8	50 6	B1A	YG^2	Possibly should be YG^1?
γ Pisc. Aust.	22 47·0	33 24	A	Y^2	Spectrum or colour wrong?

TABLE IV.

Summary of Analysis of 1360 bright Stars.

(*Combined Results.*)

Group.	Division.	Spectra.	Type.	O	YG^1	Y^1	OrY^1	Y^2	OrY^2	Or^2	Y^3	OrY^3	Or^3	OrR^3	R^3	Stars.
1	I*a*.	Oa to B9A	Helium stars	125	69	69	8	8	3	...	...	...	..	...	...	282
2	I*b*.	A ,, A5F	Hydrogen stars	168	80	104	11	14	...	...	...	...	...	...	...	377
3	I.–II.	F ,, F5G	α Carinæ type	3	11	78	8	23	8	...	6	...	...	...	...	137
4	II.	F8G ,, G5K	Solar stars	...	3	26	12	77	29	4	21	5	3	...	...	180
5	II.–III*a*.	K	Arcturus type	...	...	3	12	86	68	9	47	10	6	...	...	241
6	II.–III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	4	18	4	7	16	20	6	...	75
7	III.	Ma to Md	Betelgeuse type	...	...	1	2	2	26	13	4	4	11	3	2	68
			Total	296	163	281	53	214	152	30	85	35	40	9	2	1360

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Grouping together O, YG^1, Y^1, and OrY^1—the last 3 being *white* with the faintest perceptible tinge of colour; Y^2, OrY^2, and Or^2 as *pale* tints; Y^3, OrY^3, and Or^3 as full or *normal* tints; OrR^3 and R^3 as *ruddy* tints; we have—

White, or nearly white, stars	793 :	p. cent.	58·3 :	55·2	(Fr's obs.	1884–6).
Pale tints, yel. to orange ,,	396 :	,,	29·1 :	35·2	,,	,,
Full ,, ,, ,,	160 :	,,	11·8 :	9·6	,,	,,
Ruddy tints, orange-red and red stars, ...	11 :	,,	·8 :	·0	,,	,,
	1360		100·0	100·0		

The last column gives the percentage results I found in 1884–6 from 1744 stars, and it is interesting to note the comparison.

It will be seen that the proportion of colourless stars is similar in groups 1 and 2, the *maximum* for both series being in O (white). In group 3 the typical tint is Y^1 (yellowish-white); in group 4 it is Y^2 (pale yellow); and in group 5 it lies between Y^2, OrY^2 (pale orange-yellow), and Y^3 (normal yellow). The reason for making a subdivision in II.–III. was that there were *two maxima*—the other falling in OrY^2, OrY^3 (normal orange-yellow), and Or^3 (normal orange) = group 6. The last group is very similar to 6 in colour distribution, and it would be difficult to tell merely by eye observation of colour to which of these groups a star belonged, although the spectra are essentially different. On the whole, there is undoubtedly a striking agreement between the colours and spectra of stars; but as the spectral types shade off almost imperceptibly into each other (though in a rational sequence), so likewise do the tints of the stars. It is this overlapping which is responsible for most of the apparent departures from the normal; and we must also remember that the tints of two stars may be apparently similar even with a different arrangement of lines (see *Problems in Astrophysics*, by Miss Clerke, p. 263), whilst two stars of similar spectra may differ perceptibly in tint.

In connection with this subject it may be mentioned that there is a curious affinity between Helium stars (B type) and *bright* line spectra (O type), with the *Galaxy*. Some of the latter type are associated, too, with *nebulæ*, as 15 (S) Monocerotis, ι and θ Orionis, and η Carinæ (which also has a bright line spectrum, though very peculiar). *All* the bright line spectra met with in this investigation were in or near the Milky Way; and this becomes still more remarkable when we remember that *all* the "Wolf-Rayet" stars (some 70 in number), *all* the temporary stars (novæ), and the majority of short-period variables are also found in this region. The Galaxy seems to be the plane of origin of some of the most striking phenomena in the stellar universe; and such association cannot be merely accidental, but must be the result of some grand physical law, at present undiscovered.

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On the "Owl" Nebula, Messier 97 = N.G.C. 3587. 1860.0. $\alpha = 11^h 6^m 40^s$. $\delta = +55^\circ 46'.7$. By E. E. Barnard. (Plate 3.)

There has always been much interest attached to the great reflecting telescope of Lord Rosse. This giant instrument was used mostly in the study of the nebulæ, for which its great light-grasping power made it singularly useful. All the well-known nebulæ were studied with it, and drawings or sketches were made of many of them. There is little known as to the performance of the instrument on objects where definition was specially required. A comparison with the large modern refractors can only be had, therefore, through the agency of the nebulæ. Such a comparison must be crude at best from the difference in climate, observers, etc. Nevertheless, it would seem possible to form some idea of the power of the telescope in dealing with the nebulæ by a comparison of the drawings and descriptions with the present appearance of these objects as seen in the actual sky. To compare these drawings with photographs of the nebulæ would be very unfair, because of the extraordinary power of the sensitive plate compared with that of the eye when dealing with such objects.

A visual comparison of this kind would be well worth while, and might lead to important information concerning probable changes in the nebulæ, though there seems to be but little hope of anything in this direction except through the aid of photography at very long intervals of time.

The relative amount of light collected by the 40-inch refractor of the Yerkes Observatory and the 6-foot Rosse reflector would be 1 : 32 for a point source. If the relative effectiveness were the same, the 6-foot should have shown an object 32 times fainter than could be seen with the 40-inch telescope. Inasmuch as the great speculum was of metal, there must have been a serious loss of light to begin with. The power of the instrument must also have varied greatly according to the condition of the surface of the speculum, for Lord Rosse stated that it was subject to considerable tarnish because of the necessary amount of copper in the material.

I have examined, both with the 36-inch of the Lick Observatory and the 40-inch here, a large number of the nebulæ—especially of the planetary nebulæ—which were drawn by Lord Rosse and his assistants. From their observations, I believe, on the whole, that the 40-inch telescope will show anything that could have been seen with the great reflector, even where light alone is concerned. True, there are some details of the nebulæ in the Rosse drawings that are not visible in the 40-inch. At the same time there are others that the great reflector failed to see which are visible in the 40-inch. There is little to be said on this point, therefore, without prejudice.

Very often the Rosse drawings show fringes around the planetary nebulæ, or "beards," that are not seen in the 40-inch. I do not know that these are verified by photographs. One is almost